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IS 10242-3-10 (1992): Electrical installations in ships, Part 3: Equipment, Section 10: General construction and test requirements for low voltage shipboard power cables [ETD 20: Electrical Installation]

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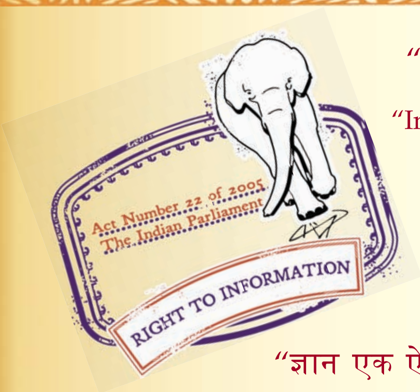

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जहाजों में विद्युत संस्थापन

भाग 3 उपस्कर

अनुभाग 10 अल्पवोल्टता के समुद्री पावर केबलों का सामान्य निर्माण और परीक्षण अपेक्षाएं — विशिष्टि

Indian Standard

ELECTRICAL INSTALLATIONS IN SHIPS

PART 3 EQUIPMENT

Section 10 General Construction and Test Requirements for Low Voltage Shipboard Power Cables — Specification

UDC 629·12·066 : 621·316·174 : 621·315·21

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BUREAU OF INDIAN STANDARDS
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Electrical Equipment Installations in Ships and Offshore Structures Sectional Committee, ETD 26

FOREWORD

This Indian Standard (Part 3/Section 10) was adopted by the Bureau of Indian Standards, after the draft finalized by the Electrical Equipment and Installations in Ships Sectional Committee had been approved by the Electrotechnical Division Council.

This standard (Part 3/Section 10) is one among the series of Indian Standards on electrical installations in ships. Other standards in the series are:

- Part 1 General
- Part 2 System design
- Part 3 Equipment
- Part 4 Installation and test of completed installation
- Part 5 Special features

In Part 3, for ease in reference, Sections 10 to 19 have been reserved for the low and medium voltage power cables while Sections 20 to 29 would deal with telecommunication cables for use in ships.

This standard (Part 3/Section 10) deals with the general constructional and test requirements for low voltage shipboard power cables. Other Sections dealing with the low voltage power cables are as follows:

- Section 11 Insulating materials for shipboard power cables
- Section 12 Choice and installation of cables for low voltage power systems
- Section 19 Sheathing materials for telecommunication and power shipboard cables

In this standard, for details of tests methods reference has been made to appropriate parts of IS 10810 'Methods of test for cables', which is, therefore, a necessary adjunct to this standard. In the preparation of this standard, assistance has been taken from IEC Pub 92 : 350 'Electrical installations in ships : Part 350 Low-voltage shipboard power cables — General construction and test requirements', issued by the International Electrotechnical Commission (IEC).

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

ELECTRICAL INSTALLATIONS IN SHIPS

PART 3 EQUIPMENT

Section 10 General Construction and Test Requirements for Low Voltage Shipboard Power Cables — Specification

1 SCOPE

1.1 This standard (Part 3/Section 10) specifies the general constructional requirements and the general test recommendations for shipboard cables with copper conductors intended for low voltage power systems at voltages up to and including 0·6/1 kV.

SECTION 10 A : GENERAL

2 REFERENCES

2.1 The Indian Standards listed in Annex A are necessary adjuncts to this standard.

3 DEFINITIONS

3.0 For the purpose of this standard, the following definitions shall apply.

3.1 Definitions Concerning the Cable

3.1.1 *Insulated Cables*

An assembly consisting of:

a) one or more cores;

b) their individual covering(s), if any;

c) assembly protection, if any;

d) protective covering(s), if any.

Additional uninsulated conductor(s) may be included in the cable.

3.1.2 *Conductor*

That part of the cable which has the specific function of carrying current.

3.1.3 *Stranded Conductor*

A conductor consisting of a number of individual wires, all or some of which generally have a helical form.

NOTE — The stranded conductor may be circular or shaped.

3.1.4 *Core*

An assembly comprising a conductor and its own insulation.

3.1.5 *Flexible Cable*

A cable which is required to be capable of being flexed while in service and of which the structure and materials are as such to fulfill the requirement.

3.1.6 *Cord*

A flexible cable with a limited number of conductors of small cross-sectional area.

3.1.7 *Length of Lay*

The axial length of one complete turn of the helix formed by one of the cable components.

3.1.8 *Separator*

A thin layer, used as a barrier to prevent mutually detrimental effects between different components of a cable, such as between conductor and insulation or between insulation and sheath.

3.1.9 *Filler*

The material used to fill the interstices between the cores of a multiconductor cable.

3.1.10 *Inner Covering*

A non-metallic covering which surrounds the assembly of the cores (and fillers, if any) of a multiconductor cable and over which the protective covering is applied.

3.1.11 *Sheath*

A uniform and continuous tubular covering consisting of non-metallic material, generally extruded.

3.1.12 *Oversheath*

A non-metallic sheath applied over a metallic covering, constituting the outermost sheath of the cable.

3.1.13 *Armour*

A covering consisting of metal tape(s) or wires, generally used to protect the cable from external mechanical effect.

3.1.14 *Braid*

A covering formed from plated metallic or non-metallic material.

3.2 Definitions of Dimensional Values

3.2.1 *Nominal Value*

A value by which a quantity is designated and which is often used in tables. Usually, nominal

values give rise to values to be checked by measurements taking into account specified tolerances.

3.2.2 *Approximate Value*

A value which is neither guaranteed nor checked; it is used, for example, for the calculation of other dimensional values.

3.2.3 *Median Value*

When several test results have been obtained and ordered in an increasing (or decreasing) succession, the median value is the middle value if the number of available values is odd, and the mean of the two middle values, if the number is even.

3.2.4 *Fictitious Values*

A value calculated according to the 'Fictitious Method' described in Annex B.

3.3 Definitions Concerning the Tests

3.3.1 *Routine Tests*

Routine tests are tests made on all finished cable lengths to demonstrate the integrity of the cable.

NOTE — By agreement between the purchaser, the manufacturer and when involved, the approval organization (making reference, for example, to results of quality control procedure), the number of lengths of finished cable on which these tests shall be carried out may be reduced.

3.3.2 *Acceptance Tests*

Acceptance tests are tests made by the manufacturer on samples of completed cable or components taken from a completed cable, at a specified frequency, so as to verify that the finished product meets the design specifications.

3.3.3 *Type Tests*

Type tests are tests required to be made by a manufacturer before supplying on a general commercial basis a type of cable covered by this standard, in order to demonstrate satisfactory performance characteristics to meet the intended application. These tests are of such a nature that, after they have been made, they need not be repeated, unless changes are made in the cable materials or design which might change the performance characteristics.

SECTION 10 B : CONSTRUCTION

4 CONDUCTORS

4.1 Material

The conductors shall consist of plain or tin-coated annealed copper.

4.2 Metal Coating and Separator

The component copper wires shall be metal-coated when used for conductors having a thermosetting insulation, unless a separator between the conductor and the insulation is provided. The same applies to thermosetting insulation provided suitable type test demonstrate that no harmful effects occur.

For conductors having thermoplastic insulation, the metal coating may be omitted. The metal coating shall be considered as satisfactory, if, on visual inspection, the wire surface appears smooth, uniform and bright and the insulation does not adhere to the conductor.

If a chemical test is required it shall be carried out with the methods and requirements specified in Annex F.

4.3 Class and Form

The conductors considered in this standard are intended only for fixed installations and shall comply with IS 8130 : 1984. Stranded circular non-compacted, compacted and sector-shaped conductors are permitted.

The nominal cross-sectional area of the conductors shall have one of the values specified in IS 8130 : 1984 with the following limitations:

a) for all types of conductors, the maximum value of the cross-sectional area shall not, in general, exceed 300 mm^2; and

NOTES

1 For any cable requiring larger conductors, they should comply with requirement for Class 2 of IS 8130 : 1984.

i) Circular non-compacted conductors shall not be less than 1 mm^2 nominal cross-sectional area, and;

ii) Circular compacted conductor shall not be less than 10 mm^2 nominal cross-sectional area.

2 Cross-sectional areas lower than 10 mm^2 are *under consideration*. Sector-shaped conductors shall not be less than 25 mm^2 nominal cross-sectional area.

3 Conductors for cables suitable for portable use in ships are *under consideration*.

b) All conductors shall have a regular shape, free from sharp projections and other defects liable to damage the insulation. Compliance with these requirements is checked by the appropriate test requirements specified in Section 10 C of this standard.

5 INSULATION

5.1 Material

The insulation shall consist of one of the insulating compounds considered in IS 10242 (Part 3/Sec 11) : 1986.

5.2 Application of the Insulation

The insulation shall be extruded in a single layer closely to the conductor or to the separator, if any.

It shall be possible to remove the insulation without damaging the conductor or the metal coating, if any.

5.3 Insulation Thickness

The insulation thicknesses are specified for each type of cable in the relevant standard.

The average thickness of the insulation shall be not less than the value specified for each type of insulation and conductor cross section.

The thickness at any point may be less than the specified value provided that the difference does not exceed 0·1 mm + 10 percent of the specified value.

6 CABLING

6.1 The cores of a multicore cable shall be laid up. The spaces between the cores shall be filled (*see* 7) so as to obtain an assembly having an essentially circular cross section.

The filling may be omitted in multicore cables having conductor nominal cross section not exceeding 4 mm².

7 INNER COVERING, FILLERS AND BINDER

7.1 Material

The inner covering, if any, may be extruded or lapped, as specified in the relevant standard of the cable.

The inner covering, fillers and binders, if any, shall be of non-hygroscopic suitable material, capable of withstanding the temperature arising when the conductors are operating at their normal temperature, and compatible with the insulating material.

An open helix of suitable tape is permitted as a binder before application of an extruded inner covering. The thickness of the binder tape shall be optional.

When rubber like or plastic inner covering or fillers are specified, they should consist of rubber (including regenerated and/or non-vulcanized rubber) or plastic compounds, and shall be resistant to moisture.

When a non-metallic sheath is applied directly over the inner covering or the fillers, it may (at manufacturer's option) substitute partially or totally for the inner covering or fillers.

When a 'watertight cable' is specified, the spaces among cores and sheath and the interstices in the conductor stands shall be filled so as to obtain a continuous sealing all along the cable, which shall be particular comply with the water-tightness test specified in **11.10**.

7.2 Inner Covering Thickness

The approximate thickness of the extruded or lapped inner coverings, if any, are specified in the relevant standard for the cable.

8 PROTECTIVE COVERING

8.1 Constituent Elements of Protective Covering

The protective covering of any cable consists of one or more 'constituent elements' which shall be specified by the relevant standard for the cable. The following types of 'constituent elements' are considered in this standard:

a) *Metallic Elements*
   i) Metal braid armour,
   ii) Metal wire armour, and
   iii) Metal tape armour.

b) *Non-metallic Elements*
   i) thermosetting or thermoplastic sheath,
   ii) impregnated fibrous braid,
   iii) bedding for metal armour, and
   iv) paint for metal armour.

8.2 Metal Braid Armour

The standard type of braid armour shall be made of zinc-coated (galvanized) steel wires complying with the galvanizing test specified in **11.12** and Annex G copper tinned copper or copper-alloy wires. On special request, the braid may be formed of tinned copper wires or of aluminium alloy wires with protection against corrosion.

The 'coverage density' of the braid shall be such that the weight of the braid is at least 90 percent of the weight of a tube of the same metal, having an internal diameter equal to the calculated internal diameter under the braid and a thickness equal to the nominal diameter of the wires forming the braid.

The diameter under the braid is calculated with the fictitious method given in Annex B and C. [Test method, *see* **11.6** (b)].

NOTE — An alternative method for evaluating the 'coverage density' is given by the following formula giving the 'filling factor', F in per unit :

$$F = \frac{NPd}{\sin \alpha}$$

where

α = slope angle between the cable axis and the braid wires,

d = diameter of braid wire,

N = number of wires per carrier, and

P = number of picks per millimetre.

The corresponding 'coverage density', expressed as a percentage, is given by the formula:

$$G = \frac{\pi}{2} . F. 100$$

To obtain the minimum value of G (90 percent) the minimum value of F should be 0·573.

8.3 Metal Wire Armour

The standard type of metal wire armour shall consist of zinc-coated mild steel wires, having an elongation at break of at least 12 percent and complying with the galvanizing test specified in **11.12** and Annex G.

NOTE — For other requirements, guidance can be taken from IS 3975 : 1979.

On special request, wires may be of a non-magnetic material instead of steel. Also on special request and where the diameter under armour is greater than 15 mm, a flat wire armour may be used.

The wires should be applied over the bedding so as to form a uniform and substantialy uninterrupted cylindrical layer, and so as to assure sufficient flexibility for the finished cable.

8.4 Metal Tape Armour

The standard type of metal tape armour shall be made of annealed steel tapes which, on special request, may be galvanized. Tapes of non-magnetic metals (for instance, copper or aluminium-alloys) may be used, on special request, in place of steel tapes.

NOTE — The risk of corrosion shall be considered when using aluminium-alloys.

The armour shall, in general, be formed of two tapes wound over the bedding in the same direction so that the gap in the first layer is not more than one half of the tape width and the second layer covers this gap with an overlap.

Particular types of metal tape armours (for instance, consisting of one tape) may be permitted, provided their mechanical characteristics are specified. For cables whose diameters under the bedding is less than 10 mm the use of a metal tape armour is not recommended.

8.5 Dimensions of the Metal Armours

For the purpose of this standard, when wire diameters, tape thicknesses, and other similar armouring dimensions are specified, they shall be understood as nominal values complying with **11.6**.

8.6 Non-metallic Sheath

8.6.1 *Material*

The sheath shall consist of one of the sheathing compounds considered in IS : 10242 (Part 3/Sec 19) : 1990. The quality of the sheathing material shall be suitable for the operating temperature of the cable.

8.6.2 *Thicknesses of the Sheath*

The thicknesses of the sheaths are specified in the relevant standard for each type of cable. The average of the sheath thickness shall be not less than the specified value.

The thicknesses at any point may be less than the specified value but shall not fall below 85 percent of the specified nominal thickness by more than 0·1 mm for sheaths applied on a smooth cylindrical surface, or below 85 percent of the specified nominal thickness by more than 0·2 mm for sheaths applied on an irregular cylindrical surface.

8.7 Impregnated Textile Braid

The textile braid, if permitted, shall be of cotton, hemp, glass, synthetic or other equivalent textile fibre. It shall be effectively impregnated with a compound which is resistant to moisture and free from deleterious action upon the various materials constituting the cable.

8.8 Bedding for Armour

When tapes are used as a bedding, they shall be wound in such a manner that each tape covers the gap (if any) between the adjacent edges.

Woven tapes (for instance, cotton or glass tapes) should be saturated or coated with a moisture resisting compound.

Synthetic tapes (for instance, PVC tapes) do not need any coating.

When fibrous rovings are used (for instance, jute or glass rovings), they shall be wound in close spirals and should be saturated and filled with moisture resisting compound.

When a fibrous braid is used as a bedding, it shall comply with **8.7**. When a non-metallic sheath is used as a bedding, it shall comply with **8.6**. The relevant thickness shall be considered as approximate value.

8.9 Removal of the Protective Coverings

It shall be possible to remove easily:

- the outer sheath from the metallic covering, and
- the metallic covering from the inner covering or the inner sheath.

SECTION 10 C : TEST REQUIREMENTS

9 TEST CONDITIONS

9.1 Ambient Temperature

Unless otherwise specified, in the details for the particular test, voltage tests shall be made at room temperature and other tests at an ambient temperature of 27 ± 2°C.

9.2 Frequency and Waveform of Power Frequency Test Voltages

The frequency of the alternating test voltages shall be in the range 40 Hz to 60 Hz. The

waveform shall be substantially sinusoidal. The values coated are rms values.

10 ROUTINE TESTS

10.1 General

The routine tests required by this standard are:

a) Measurement of the electrical resistance of conductors (*see* **10.2**),

b) High voltage test (*see* **10.3**), and

c) Insulation resistance test (*see* **10.4**).

The routine tests shall normally be carried out on all finished cable lengths, but the number of lengths may be reduced by agreement between the purchaser, manufacturer and, when involved by the approval organization (making reference, for instance to results of quality control procedures).

The routine tests may be carried out, at manufacturer's option, either on delivery lengths or on manufacturing lengths before cutting them into delivery lengths.

10.2 Electrical Resistance of Conductors

a) For multicore cables, the measurement shall be made on all conductors of each cable length selected for the routine test.

b) The completed cable length, or a sample therefrom, shall be tested in the test-room, which shall be maintained at a reasonably constant temperature, for at least 12 h before the tests. If it is doubtful whether the conductor temperature is same as the room temperature, the resistance shall be measured after the cable has been in the test room for 24 h. Alternatively, the resistance shall be measured on a sample of conductor conditioned for at least 1 h in a temperature-controlled bath.

The measured value of resistance shall be corrected to at temperature of 20°C and 1 km length in accordance with the formulae and factors given in IS 8130 : 1984.

c) The dc resistance of each conductor at 20°C shall not exceed the appropriate maximum value specified in IS 8130 : 1984.

NOTE — For methods of tests, guidance may be taken from IS 10810 (Part 5) : 1984.

10.3 High Voltage Test

a) The high voltage test shall be made at ambient temperature, using at manufacturer's option either alternating voltage at power frequency or direct voltage or, for spark testing, high frequency or other forms of voltage.

b) Single core cables without metallic covering shall be immersed in water at room temperature for 1 h and the test voltage then applied for 5 min between the conductor and the water.

Alternatively, for single core cables without sheath, at manufacturer's option, a spark test shall be carried out on the cable. The spark test equipment shall detect a puncture in the insulation having a diameter equal to or greater than half of the specified insulation thickness. The recovery time of the spark tester shall be not greater than 1 second. The magnitude and the presence of the voltage shall be such that with the electrode system employed and at the speed employed for the passage of the cable through the spark tester the test requirements are effectively met. The reference method to be used to establish the efficacy of the spark testing equipment is given in Annex E.

c) For multicore cables and single core cables with metallic covering, the test voltage shall be applied for 5 min in succession between each insulated conductor and all the other conductors and metallic covering, if any. The conductors may be suitably connected for successive applications of the test voltage to limit the total testing time, provided that the sequence of connections ensures that the voltage is applied for at least 5 min without interruption between each conductor and each other conductor and between each conductor and the metallic covering, if any.

d) Unless otherwise stated in the relevant standard for the cable, the values of the test voltage for the standard rated voltages are given below:

Rated Voltage of Cable Uo/V (kU)	*Test Voltage for 5 Min* Alternating Current (ac) (kV)	Direct Current (dc) (kV)
Up to and including		
0·15/0·25	1·5	3·6
0·6/1·0	3·5	8·4

e) The test voltage shall be increased gradually to the specified value and no breakdown of the insulation shall occur.

NOTE — For methods of tests guidance can be taken from IS 10810 (Part 45) : 1984.

10.4 Measurement of Insulation Resistance

a) The Insulation resistance shall be measured at ambient temperature using a dc voltage of 80 V to 500 V after the high-voltage test has been carried out.

b) The measurement shall be in general effected 1 min after application of voltage.

In certain cases, however, in order to reach a substantial steady state condition, the time of application may be prolonged up to a maximum of 5 min.

c) The connection procedure in carrying out the test of different types of cables shall be as follows:

i) For single core cables with metallic covering, the insulation resistance measurement shall be performed between the conductor and metallic covering;

ii) For single core cables without metallic covering, the insulation resistance measurement shall be performed between the conductor and the water in which the cable shall be immersed at least one hour before the test;

iii) For cables having 2 to 5 conductors, with or without metallic covering, the insulation resistance measurement shall be performed in turn between each conductor and all other conductors connected together and to the metallic covering, if any;

iv) For cables having more than five conductors, the insulation measurement test shall be performed; first between all conductors of uneven number in all layers and all conductors of even number in all layers; second between all conductors of even layers and all conductors of uneven layers; third, if necessary, between the first and the last conductor of each layer having an uneven number of conductors.

d) The measurement values of the insulation resistance shall be corrected to the reference temperature of 20°C by using an appropriate temperature correction factor based on experimental results obtained on the insulation material concerned.

e) The insulation resistance constant K_1 shall be calculated using the formula:

$$K_1 = \frac{LR \times 10^{-9}}{\log_{10}\frac{D}{d}} \ (M\Omega \text{ km})$$

where

L = length of the cable, in metres;

R = measured insulation resistance, in ohms, corrected to 20°C;

D = outer diameter of the insulation, in millimetres; and

d = inner diameter of the insulation, in millimetres.

The calculated value of K_i shall be not less than the value specified, for the relevant insulating material, in Table 2 of IS 10242 (Part 3/ Sec 11) : 1986.

NOTES

1 For the core of shaped conductors the ratio D/d is the ratio of perimeter over insulation to the perimeter over the conductors.

2 For methods of tests guidance can be taken from IS 10810 (Part 43) : 1964.

11 ACCEPTANCE TESTS

11.1 General

The acceptance tests required by this standard are:

a) Conductor examination (*see* **11.3**),

b) Check of dimension (*see* **10.4** to **11.7**),

c) Hot set test for EPR and XLPE insulation (*see* **11.8**),

d) Test at low temperature for PVC (*see* **11.9**),

e) Water tightness test (*see* **11.10**),

f) Test of the metal coating of the copper wires (*see* **11.11**), and

g) Galvanizing test (*see* **11.12**).

11.2 Frequency of Acceptance Tests

a) *Conductor Examination and Check of Dimensions*

Conductor examination, measurement of the thickness of insulation and sheath and measurement of the overall diameter, if required by the purchaser, shall be made on one length from each manufacturing series of the same type of size of cable, but shall be limited not to be more than 10 percent of the number of lengths at any contract.

b) *Electrical and Physical Test*

By agreement between the purchaser and manufacturer, the test specified shall be made on samples taken from cables manufactured for the contract, provided that the total length in the contract exceeds 2 km of multicore cables or 4 km of single-core cables on the following basis:

Cable Length				*Number of Samples*
Multicore Cables		Single Core Cables		
Above (km)	Up to & Including (km)	Above (km)	Up to & Including (km)	
2	10	4	20	1
10	20	20	40	2
20	30	40	60	3
etc		etc		etc

11.3 Conductor Examination

Compliance with the requirements for conductor construction of IS 8130 : 1984 shall be checked

by inspection and by measurement when practicable.

11.4 Measurement of Thickness of Insulation

a) *Sampling*

Each cable length selected for the test shall be represented by two pieces of cable, taken one from each end, after having discarded, if necessary, any portion which may have suffered damage.

For cables having more than three cores of equal nominal cross-section the number of cores on which measurement is made shall be limited to either three cores or 10 percent of the cores, whichever is the larger.

If the average thickness measured, or the lowest value measured, on one of the two pieces, fails to meet the requirements specified in **11.4** (c), two other pieces shall be checked. If both of the further pieces meet the specified requirements, the cable is deemed to comply but if either do not meet the requirements, the cable is deemed not to comply.

b) *Procedure*

The test procedure shall be in accordance with IS 10810 (Part 6) : 1984.

c) *Requirements*

For each piece of core, the average values which shall be rounded off to the nearest 0·1 mm (*see* Annex C), shall be not less than the specified nominal thickness and the smallest value shall not fall below 90 percent of the specified nominal thickness by more than 0·1 mm.

11.5 Measurement of Thickness of Non-metallic Sheaths (Excluding Inner Coverings)

a) *Sampling*

Each cable length selected for the test shall be represented by two pieces of cable, taken one from each end after having discarded, if necessary, any portion which may have suffered damage.

If the average thickness measured or the lowest value measured on one of the two pieces fails to meet the requirements specified in **10.5** (c), two other pieces shall be checked. If both of the further pieces meet the specified requirements, the cable is deemed to comply, but if either do not meet the requirements, the cable is deemed not to comply.

b) The test procedure shall be in accordance with IS 10810 (Part 6) : 1984.

c) *Requirements*

Each piece of sheath shall comply with the following:

i) For a sheath applied on a smooth cylindrical surface (for example, on an inner covering or the insulation of the single core):

The average, which shall be rounded off to the nearest 0·1 mm (*see* Annex C) of the measured values shall not be less than the specified nominal thickness; the smallest value shall not fall below 85 percent of the specified nominal thickness by more than 0·1 mm.

ii) For a sheath applied on an irregular cylindrical surface (for example, a penetrating sheath embodying an inner covering or a sheath applied directly over a tape or wire armour), the smallest measured value shall not fall below 85 percent of the specified nominal thickness by more than 0·2 mm.

11.6 Dimensions of Armouring

a) A number of micrometer measurements should be made on some specimens selected at random, in order to check that metal wire diameters and metal tape thicknesses comply with the nominal values. Compliances should be understood as follows:

All individual measured values to be not smaller than 90 percent of the nominal value minus 0·03 mm and not greater than 110 percent of the average value plus 0·03 mm.

b) Checking of the coverage density of a metal braid armour should be carried out by weighing a braid specimen at least 25 mm long; the weight should be not less than 90 percent of the calculated weight of an equivalent tube as specified under **8.2**. Alternatively, the filling factor shall not be less than 0·573 (*see* **8.2**).

11.7 Measurement of External Diameter

If the measurement of the external diameter of the cable is required as a special test, it shall be carried out in accordance with IS 10810 (Part 6) : 1984.

11.8 Hot Set Test for EPR and XLPE Insulation

a) *Procedure*

The sampling and test procedure shall be carried out in accordance with IS 10810 (Part 30) : 1984, employing the conditions given in Table 4 of IS 10242 (Part 3/Sec 11) : 1986.

b) *Requirements*

The test results shall comply with the requirements given in Table 4 of IS 10242 (Part 3/Sec 11) : 1986.

11.9 Test for the Behaviour of PVC Insulation and Sheath at Low Temperature

a) *Procedure*

The sampling and test procedure shall be in accordance with IS 10810 (Parts 20 and 21) : 1984, employing the test temperature specified in Table 4 of IS 10242 (Part 3/Sec 11) : 1986 for the insulation, or in Table 3 of IS 10242 (Part 3/Sec 19) : 1990 for the sheath.

b) *Requirements*

The test results shall comply with the requirements given in IS 10810 (Parts 20 and 21) : 1984.

11.10 Watertightness Test

When a cable is required to be 'Watertight' this test should be carried out with the method and requirements given below:

a) *General*

If a cable is required to be 'watertight' the volume of water lost by a cable specimen, when tested in the conditions specified in points (b), (c) and (d) below, should not be greater than the value V calculated from the formula:

$$V + 10\,N(A + 2), \text{ in cm}^3$$

where

N = the number of conductors in the cable, and

A = the cross-section of each conductor in mm^2.

In any case, the lost volume should not be more than 2 000 cm^3.

b) *Specimens*

The specimens should be a piece of finished cable, 1·5 m long, which has not been subjected to prior flexing or heating or any other test. The metal armour may be removed from the ends, without disturbing the cable, to facilitate making a watertight gland.

c) *Apparatus*

A small water tank, fitted with watertight stuffing tubes, should be connected with a device permitting application of a controlled pressure, which is measured by a gauge and with a device permitting detection of leakages, if any. The fittings used for securing specimens to the tank should neither construct nor widen the ends of the said specimens and should not give rise to leakage.

d) *Procedure*

One end of each specimen should be secured to the tank then the water pressure raised in about 1 min to 0·1 MPa and maintained at this value for 3 h. Any water coming from the other end or from the surface or the specimen should be gathered and measured.

11.11 Test of the Metal Coating of Copper Wires

The metal coating should be considered satisfactory, if at a visual inspection (*see* **11.3**), the wire surface appears smooth and uniform and the insulation is not adherent to the conductor.

If a chemical test is required, it should be carried out with the method and requirements specified in Annex F (colorimetric method).

11.12 Galvanizing Test

When a galvanizing test is required for checking the resistance of steel wires against rusting, the immersion test specified in Annex G should be carried out on wire specimens taken from the cable sampled. If a paint [*see* **8.1** (b) (iv)] is applied on the armour, this test should be made on specimens taken from wires prior to their application on the cable.

NOTE — For method of test guidance may be taken from IS 10810 (Part 39) : 1984.

12 TYPE TESTS (ELECTRICAL)

12.1 General

The type tests required by this standard, and to be applied on samples of completed cable 10 to 15 m long, are the following:

a) Insulation resistance measurement at room temperature (*see* **12.2.1**).

b) Insulation resistance measurement at operating temperature (*see* **12.2.2**).

c) Increase of the ac capacity after immersion in water (*see* **12.3**).

d) High voltage test for 4 h (*see* **12.4**).

12.2 Insulation Resistance Measurement

12.2.1 *Measurement at Room Temperature*

a) *General*

This test shall be made on the sample length before any other electrical test. All outer covering shall be removed and the cores shall be immersed in water at room temperature at least 1 h before the test. The measurement shall be made between conductor and water.

If requested, measurement may be confirmed at 27 ± 2°C.

The dc test voltage shall be 80 V to 500 V and shall be applied for not less than 1 min and not more than 5 min.

b) *Calculations*

The 'insulation resistance constant k_i' shall be calculated from the formula:

$$k_i = \frac{l \, . \, R \times 10^{-11}}{\log_{10} \frac{D}{d}} = 10^{-11} \times 0.367 \rho, \ \text{M}\Omega \text{ km}$$

Also the volume resistivity may be calculated from the measured insulation resistance by the following formula:

$$\rho = \frac{2 \pi l R}{l_n \frac{D}{d}}$$

where

R = measured insulation resistance in ohms,

l = length of the cable in centimetres,

D = outer diameter of the insulation in millimetres, and

d = inner diameter of the insulation in millimetres.

c) *Requirements*

The values calculated from the measurement shall be not less than those specified in Table 2 of IS 10242 (Part 3/Sec 11) : 1986.

NOTE — For the core of shaped conductors, the ratio D/d is the ratio of perimeter over insulation to the perimeter over the conductors.

12.2.2 *Measurement of Maximum Rated Temperature*

a) The cores of the cable sample with all outer coverings removed shall be immersed in water which shall be heated at the specified temperature for at least 1 h before test.

The dc test voltage shall be 80 V to 500 V and shall be applied for not less than 1 min and not more than 5 min.

b) *Calculations*

The insulation resistance constant and/or the volume resistivity shall be calculated from the insulation resistance by the formulae given in **12.2.1** (b).

c) *Requirements*

The values calculated from the measurement shall be not less than those specified in Table 2 of IS 10242 (Part 3/Sec 11) : 1986.

12.3 Increase in ac Capacitance After Immersion in Water

When required by the purchaser and agreed by the manufacturer, the water absorption test shall be carried out in accordance with the following method:

a) *Preparation of Test Specimens*

Every test specimens shall consist of a core sample 4·50 m long in which any covering of the insulation (including vulcanization tape if any) has been removed.

b) *Apparatus*

A water tank shall be used such that the central portion of the specimens is immersed over a length of 3 m whilst a length of 0·75 m is maintained above the water level at each end. The water shall be thermostatically maintained at a temperature of 50 ± 2°C. The water level shall be maintained constant.

c) *Procedure*

The test specimens shall first be dried for 24 h in an oven, the air which is maintained between 70°C and 75°C. As soon as the test specimen is removed from the oven, it shall be immersed, as indicated above, in tap water having previously been heated to 50°C. The immersion shall be maintained at this temperature for 14 days.

d) *Electrical Measurements*

The capacitance between conductor and water shall be measured with low voltage ac at a frequency of 800 Hz to 1 000 Hz.

These measurements shall be carried out:

i) at the end of the first day;

ii) at the end of the seventh day;

iii) at the end of the fourteenth day;

iv) precautions being taken to ensure that the temperature and water level are the same for all measurements.

e) *Results to be Obtained*

The capacitance C_1, C_7 and C_{14} so found should comply with the following:

$$C_{14} - C_1 \leqslant 0·15 \, C_1$$
$$C_{14} - C_7 \leqslant 0·05 \, C_7$$

12.4 High Voltage Test for 4 h

The cores of the cable sample with all outer coverings removed shall be immersed in water at room temperature for at least 1 h.

A power-frequency voltage equal to three times the rated voltage Uo shall be gradually applied and maintained continuously for 4 h between the conductor and water. No breakdown of the insulation shall occur.

13 TYPE TESTS (NON-ELECTRICAL)

13.0 The non-electrical type tests required by this standard are summarized in Table 1 both for insulation and non-metallic sheaths.

13.1 Measurements of Thickness of Insulation

a) *Sampling*

One sample of each insulated cable core shall be taken from each of three places separated from each other by at least 1 m.

For cables having more than three cores of equal nominal cross-section, the number of cores on which the measurement is made shall be limited to three cores or 10 percent of the cores, whichever is larger.

b) *Procedure*

The measurement shall be made as described in IS 10810 (Part 6) : 1984.

c) *Requirements*

The average, which shall be rounded off to the nearest 0·1 mm (*see* Annex C), of all the measured values on each core shall not be less than the specified nominal thickness and the smallest measured value shall not fall below 90 percent of the specified nominal thickness by more than 0·1 mm.

13.2 Measurement of Thickness of Non-Metallic Sheaths (Excluding Inner Coverings)

a) *Sampling*

One sample of cable shall be taken from each of three places separated from each other by at least 1 m.

b) *Procedure*

The measurements shall be made as described in IS 10810 (Part 6) : 1984.

c) *Requirements*

Each piece of sheath shall comply with the following:

— For a sheath applied on a smooth cylindrical surface (for example, on an inner covering, or the insulation of a single core):

the average, which shall be rounded off to the nearest 0·1 mm (*see* Annex C), of the measured values shall not be less than the specified nominal thickness;

the smallest value shall not fall below 85 percent of the specified nominal thickness by more than 0·1 mm.

— For a sheath applied on an irregular cylindrical surface (for example, a penetrating sheath on an unarmoured multicore cable without inner covering, or a sheath applied directly over a tape or wire armour):

the smallest value shall not fall below 80 percent of the specified nominal value by more than 0·3 mm.

13.3 Tests for Determining the Mechanical Properties of Insulation Before and After Ageing

a) *Sampling*

Sampling and the preparation of the test pieces shall be carried out as described in IS 10810 (Parts 7 and 8) : 1984.

b) *Ageing Treatments*

The ageing treatments shall be carried out as described in IS 10810 (Part 11) : 1984 under the conditions specified in Table 3 of IS 10242 (Part 3 /Sec 11) : 1986.

c) *Conditioning ana Mechanical Tests*

Conditioning and the measurement of mechanical properties shall be carried out as described in IS 10810 (Parts 7 and 8) : 1984.

d) *Requirements*

The test results for unaged and aged test pieces shall comply with the requirements given in Table 3 of IS 10242 (Part 3/ Sec 11) : 1986.

13.4 Tests for Determining the Mechanical Properties of Sheaths Before and After Ageing

a) *Sampling*

Sampling and the preparation of the test pieces shall be carried out as described in IS 10810 (Parts 7 and 8) : 1984.

b) *Ageing Treatments*

The ageing treatments shall be carried out as described in IS 10810 (Part 11) : 1984, under the conditions specified in Table 2 of IS 10242 (Part 3/Sec 19) : 1990.

c) *Conditioning and Mechanical Tests*

Conditioning and the measurement of mechanical properties shall be carried out as described in IS 10810 (Parts 7 and 8): 1984.

d) *Requirements*

The test results for unaged and aged test pieces shall comply with the requirements given in Table 2 of IS 10242 (Part 3/Sec 19) : 1990.

13.5 Additional Ageing Test on Pieces of Completed Cables (Compatibility Test)

a) *General*

This test is intended to check that the insulation and sheath are not liable to deteriorate in operation due to contact with other components in the cable. The test is applicable to cables of all types.

b) *Sampling*

Samples shall be taken from the completed cable as described in IS 10810 (Part 11) : 1984.

c) *Ageing Treatment*

The ageing treatment of the pieces of cable shall be carried out in an air oven, as described in IS 10810 (Part 11) : 1984, under the following conditions:

Temperature : 10 ± 2°C above the rated operating conductor temperature of the cable or, if the operating temperature of the cable is not known 10 ± 2°C above the rated operating conductor temperature for the insulating material [*see* Table 1 of IS 10242 (Part 3/ Sec 11) : 1986].

Duration : 7 × 24 h.

d) *Mechanical Tests*

Test pieces of insulation and sheath from the aged pieces of cable shall be prepared and subjected to mechanical tests described in IS 10810 (Part 11) : 1984.

e) *Requirements*

The variations between the median values of tensile strength and elongation at break after ageing and the corresponding values obtained without ageing (*see* **13.3** *and* **13.4**) shall not exceed the values applying to the test after ageing in an air oven specified in Table 3 of IS 10242 (Part 3/Sec 11) : 1986 and Table 2 of IS 10242 (Part 3/Sec 19) : 1990 for sheath.

13.6 Loss of Mass Test on PVC Insulation and Sheaths

a) *Procedure*

The sampling and complete test procedure shall be in accordance with IS 10810 (Part 10) : 1984.

b) *Requirements*

The test results shall comply with the requirements given in Table 4 of IS 10242 (Part 3/Sec 11) : 1986 for insulation and Table 3 of IS 10242 (Part 3/Sec 19) : 1990 for sheaths.

13.7 Test for the Behaviour of PVC Insulation and Sheaths at High Temperatures (Pressure Test)

a) *Procedure*

The sampling and test procedure shall be in accordance with IS 10810 (Part 15) : 1984 employing the test conditions given in the test method and in Table 4 of IS 10242 (Part 3/Sec 11) : 1986 for insulation, and Table 3 of IS 10242 (Part 3/ Sec 19) : 1990 for sheaths.

b) *Requirements*

The test results shall comply with the requirements given in Table 4 of IS 10242 (Part 3/Sec 11) : 1986 for insulation and Table 3 of IS 10242 (Part 3/Sec 19) : 1990 for sheaths.

13.8 Test for the Behaviour of PVC Insulation and Sheath at Low Temperature

a) *Procedure*

The sampling and test procedures shall be in accordance with IS 10810 (Parts 20 and 21) : 1984, employing the test temperatures specified in Table 4 of IS 10242 (Part 3/Sec 11) : 1986 for insulation, and Table 3 of IS 10242 (Part 3/Sec 19) : 1990 for seaths.

b) *Requirements*

The results of the test shall comply with the requirements given in IS 10810 (Parts 20 and 21) : 1984.

13.9 Test for Resistance of PVC Insulation and Sheaths to Cracking (Heat Shock Test)

a) *Procedure*

The sampling and test procedure shall be in accordance with IS 10810 (Part 14) : 1984, the test temperature and period of heating being in accordance with Table 4 of IS 10242 (Part 3/Sec 11) : 1986 for insulation and Table 3 of IS 10242 (Part 3/Sec 19) : 1990 for sheaths.

b) *Requirements*

The result of the tests shall comply with the requirements given in IS 10810 (Part 14) : 1984.

13.10 Ozone Resistance Test for EPR Insulation

a) *Procedure*

The sampling and test procedure shall be carried out in accordance with IS 10810 (Part 13) : 1984. The ozone concentration and test period being in accordance with Table 4 of IS 10242 (Part 3/Sec 11) : 1986.

b) *Requirements*

The results of the test shall comply with requirements given in IS 10810 (Part 13) : 1984.

13.11 Hot Set Test for EPR and XLP Insulation

a) *Procedure*

The sampling and test procedure shall be carried out in accordance with IS 10810 (Part 30) : 1984, employing the conditions given in Table 4 of IS 10242 (Part 3/ Sec 11): 1986.

b) *Requirements*

The results of the test shall comply with the requirements given in Table 4 of IS 10242 (Part 3/Sec 11) : 1986.

13.12 Oil Immersion Test for Elastomeric Sheaths

a) *Procedure*

The sampling and test procedure shall be carried out in accordance with IS 10810 (Part 31) : 1984, employing the conditions given in Table 2 of IS 10242 (Part 3/ Sec 19) : 1990

b) *Requirements*

The results of the test shall comply with the requirements given in Table 2 of IS 10242 (Part 3/Sec 19) : 1990.

13.13 Flame Retardance Test

This test shall be carried out on pieces of completed cable. This method of test and requirements shall be those specified in IS 10810 (Part 53) : 1984.

13.14 Test for Fire-Proof or Fire-Resisting Cables

This test shall be carried out on pieces of completed cable only when specially required. This method of test and requirements shall be those specified in IS 10310 (Part 53) : 1984.

NOTE — Further part under IS 10310 carrying methods of tests for checking various characteristics for flame retardance properties of the cables are under consideration. Till such time the relevant Indian Standards are not available, the flame retardant cables may be checked in accordance with IEC Pub 331 (1970) 'Fire resisting characteristics of electric cables, and IEC Pub 332 (1970) 'Test on electric cables under fire conditions'.

Table 1 Non-Electrical Type Tests

(*Clause* 13.0)

Designation of Compounds	Insulators				Non-Metallic Sheaths			
	Thermo-Plastic	Elastomeric			Thermoplastic		Elastomeric	
	V 60	S 95	E 85	R 85	SV 1	SV 2	SE 1	SH
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1. **Dimensions**	×	×	×	×	×	×	×	×
1a Measurement of thicknesses								
2. **Mechanical properties (tensile strength and elongation)**								
2a Without ageing	×	×	×	×	×	×	×	×
2b After ageing in air oven			×					
2c After ageing in air bomb	×	×	×	×	×	×	×	×
2d After additional ageing in air oven (contamination)	×	×	×	×	×	×	×	×
2e After immersion in hot oil							×	×
3. **Thermoplastic properties**								
3a Hot pressure test (indentation)	×				×	×		
3b Behaviour at low temperature	×				×	×		
4. **Miscellaneous**								
4a Loss of mass test in air oven	×				×	×		
4b Heat shock test (cracking)	×				×	×		
4c Ozone resistance test			×					
4d Hot set test			×	×				
4e Flame retardance test					×	×	×	×

'×' indicates that the type test is to be applied.

ANNEX A

(*Clause* 2.1)

LIST OF REFERRED INDIAN STANDARDS

IS No.	*Title*
3975 : 1979	Mild steel wire, strips and tapes for armouring of cables (*first revision*)
8130 : 1984	Conductors for insulated electric cables and flexible cords (*first revision*)

IS No.	Title
10242 (Part 3/ Sec 11) : 1986	Electrical illustration in ships : Part 3 Equipment, Section 11 Insulating meterials for shipboard power cables
10242 (Part 3/ Sec 19) : 1990	Electrical installations in ships : Part 3 Equipment, Section 19 Sheathing materials for telecommunication and power shipboard cables
10810 (Part 5) : 1984	Methods of test for cables: Part 5 Conductor resistance test
10810 (Part 6) : 1984	Methods of test for cables: Parts 6 Thickness of thermoplastic and elastomeric insulation and sheath
10810 (Part 7) : 1984	Methods of test for cables: Part 7 Tensile strength and and elongation at break of thermoplastic and elastomeric insulation and sheath
10810 (Part 8) : 1984	Methods of test for cables: Part 8 Breaking strength and elongation at break for impregnated paper insulation
10810 (Part 10) : 1984	Methods of test for cable: Part 10 Loss of mass test
10810 (Part 11) : 1984	Methods of test for cables: Part 11 Thermal ageing in air
10810 (Part 13) : 1984	Methods of test for cables: Part 13 Ozone resistance test
10810 (Part 14) : 1984	Methods of test for cables: Part 14 Heat shock test
10810 (Part 15) : 1984	Methods of test for cables: Part 15 Hot deformation test
10810 (Part 20) : 1984	Methods of test for cables: Part 20 Cold blend test
10810 (Part 21) : 1984	Methods of test for cables: Part 21 Cold impact test
10810 (Part 30) : 1984	Methods of test for cables: Part 30 Hot set test
10810 (Part 31) : 1984	Methods of test for cables: Part 31 Oil resistance test
10810 (Part 39) : 1984	Methods of test for cables: Part 39 Winding test on galvanised steel strips
10810 (Part 43) : 1984	Methods of test for cables: Part 43 Insulation resistance
10810 (Part 45) : 1984	Methods of test for cables: Part 45 High voltage test
10810 (Part 53) : 1984	Methods of test for cables: Part 53 Flammability test

ANNEX B
(*Clauses* 3.2.4, B.2 *and* C-1.1)

THE FICTITIOUS CALCULATION METHOD FOR DETERMINATION OF DIMENSIONS OF PRODUCTIVE COVERINGS

B-0 The thickness of cable coverings, such as sheaths and armour, has usually been related to nominal cable diameters by means of 'step-tables'.

This sometimes causes problems. The calculated nominal diameters are not necessarily the same as the actual values achieved in production. In broderline cases, queries can aries if the thickness of a covering does not correspond to the actual diameter because the calculated diameter is slightly different. Variations in shaped conductor dimensions between manufacturers and different methods of calculation cause differences in nominal diameters and may therefore lead to variation in thickness of coverings used on the same basic design of cable.

To avoid these difficulties, the fictitious calculation method was invented. The idea is to ignore the shape and degree of compaction of conductors and to calculate fictitious diameters for formulae based on the cross-sectional area of conductors, insulation thickness and number of cores. Thicknesses of sheaths and other coverings are then related to the fictitious diameters by formulae or by tables. The method of calculating fictitious diameters is precisely specified and there is no ambiguity about the thickness of coverings to be used, which are independent of slight differences in manufacturing practices. This standardizes cable designs, thicknesses being pre-calculated and specified for each size of cable.

The fictitious calculation is used only to determine dimensions of sheath and cable coverings. It is not a replacement for the calculation of normal diameters required for practical purposes, which should be calculated separately.

B-1 GENERAL

B-1.1 The following fictitious method of calculating thicknesses of various coverings in a

cable has been adopted to ensure that any differences which can arise in independent calculations, for example, due to the assumption of conductor dimensions and the unavoidable differences between nominal and actual achieved diameters are eliminated.

B-1.2 All thickness value and diameters shall be rounded according to the rules given in Annex C to the first decimal figure.

B-1.3 Holding strips, for example, counter-helix over armour, if not thicker than 0·3 mm, are neglected in this calculation method.

B-2 METHOD

B-2.1 Conductors

The fictitious diameter (d_L) of a conductor, irrespective of shape or compactness, is given for each nominal cross-section in Table 2.

Table 2 Fictitious Diameter (d_L) of a Conductor

Nominal Cross-Section of Conductor mm²	d_L mm	Nominal Cross-Section of Conductor mm²	d_L mm
(1)	(2)	(3)	(4)
1·5	1·4	95	11·0
2·5	1·8	120	12·4
4	2·3	150	13·8
6	2·8	185	15·3
10	3·6	240	17.5
16	4·5	300	19·6
25	5·6		
35	6·7		
50	8·0		
70	9·4		

B-2.2 Cores

The fictitious diameter D_c, of any core is given by:

$$D_c = d_L + 2\ t_i, \text{ in millimetres}$$

where t_i is the nominal thickness of insulation.

B-2.3 Diameter Over Laid-Up Cores

The fictitious diameter over laid-up cores (D_f) is given by:

a) for cables having all conductors of the same nominal cross-sectional area:

$$D_f = k\ D_c, \text{ in millimetres}$$

where the cofficient k is as given in Table 3.

b) for four-core cables with one insulated conductor with reduced cross-section

$$D_f = \frac{2{\cdot}41\ (\ 3D_{c1} + D_{c2}\ )}{4}, \text{ in millimetres}$$

Table 3 Assembly Coefficient

Number of Cores	Assembly Coefficient (k)	Number of Cores	Assembly Coefficient (k)
2	2·00	25	6·00
3	2·16	26	6·00
4	2·42	27	6·15
5	2·70	28	6·41
6	3·00	29	6·41
7	3·00	30	6·41
7*	3·35	31	6·70
8	3·45	32	6·70
8*	3·66	33	6·70
9	3·80	34	7·00
9*	4·00	35	7·00
10	4·00	36	7·00
10*	4·40	37	7·00
11	4·00	38	7·33
12	4·16	39	7·33
12*	5·00	40	7·33
13	4·41	41	7·67
14	4·41	42	7·67
15	4·70	43	7·67
16	4·70	44	8·00
17	5·00	45	8·00
18	5·00	46	8·00
18*	7·00	47	8·00
19	5·00	48	8·15
20	5·33	52	8·41
21	5·33	61	9·00
22	5·67		
23	5·67		
24	6·00		

*Cores assembled in one layer.

where

D_{c1} = fictitious diameter of insulated phase conductor, including metallic layer, if any; and

D_{c2} = fictitious diameter of the insulated coductor with reduced cross-section.

B-2.4 Inner Coverings

The fictitious diameter over the inner covering, D_B is given by:

$$D_B = D + 2t_B$$

where t_B is the appropriate value of the inner coverings, if any, specified in the standard of the relevant cable.

B-2.5 Sheath

The fictitious diameter over the sheath, D_s, is given by:

$$D_s = D_u + 2t_s, \text{ in millimetres}$$

where

D_u = fictitious diameter under the sheath, and

t_s = thickness specified in the standard of the relevant cable.

B-2.6 Additional Bedding for Tape-Armoured Cables (Provided Over the Inner Covering)

Fictitious Diameter Under the Additional Bedding		*Increase in Diameter for Additional Bedding*
Above	Up to and including	
(mm)	(mm)	(mm)
—	30	1·0
30	—	1·6

B-2.7 Armour

The fictitious diameter over the armour, D_X, is given by:

i) For flat or round wire armour:

$$D_X = D_A + 2t_A, \text{ in millimetres}$$

where

D_A = diameter under the armour, and

t_A = thickness or diameter of the armour wire.

ii) For tape armour:

$$D_X = D_A + 4t_A, \text{ in millimetres}$$

where

D_A = diameter under the armour, and

t_A = thickness of the armour tape.

iii) For braid armour:

$$D_X = D_A + 5d_W, \text{ in millimetres}$$

where

D_A = diameter under the armour, and

d_W = nominal diameter of the braid wire.

ANNEX C

(*Clauses* 8.2, 11.4, 11.5, 13.1 *and* 13.2)

ROUNDING OF NUMBERS

C-1 ROUNDING OF NUMBER FOR THE PURPOSE OF THE FICTITIOUS CALCULATION METHOD

C-1.1 The following rules apply when rounding of numbers in calculating fictitious diameters and determining dimensions of component layers in accordance with Annex B.

When the calculated value at any stage has more than one place of decimals, the value should be rounded to one place of decimals, that is, to the nearest 0·1 mm. The fictitious diameter at each stage should be rounded to 0·1 mm and, when used to determine the thickness of dimension of an overlying layer, it should be rounded before being used in the appropriate formula or table. The thickness calculated from the rounded value of fictitious diameter should be in turn rounded to 0·1 mm as required in Annex B.

C-1.2 To illustrate these rules, the following practical examples are given:

a) When the figure in the second decimal place before rounding is 0,1,2,3, or 4, then the figure retained in the first decimal remain unchanged (rounding down).

Examples: 2·12 ≈ 2·1
2·449 ≈ 2·4
25·0478 ≈ 25·0

b) When the figure in the second decimal place before rounding in 9,8,7,6 or 5, then the figure in the first decimal place is increased by one (rounding up).

Examples: 2·17 ≈ 2·2
2·453 ≈ 2·5
30·050 ≈ 30·1

C-2 ROUNDING OF NUMBERS FOR OTHER PURPOSES

C-2.1 For the purposes other than those considered under **C-1.1**, it may be required that values are rounded to more than one place of decimals. This may occur, for instance, in calculating the average value of several measurement results, or the minimum value by applying a percentage tolerance to a given nominal value. In these cases, rounding shall be carried out to the number of places of decimals specified in the relevant clauses.

C-2.2 The method of rounding shall then be:

If the least figure to be retained is followed before rounding, by 0,1,2,3 or 4, it shall remain unchanged (rounding down).

If the last figure to be retained if followed, before rounding, by, 9,8,7,6 or 5, it shall be increased by one (rounding up).

2·449	≈ 2·45	rounded to two decimal places
2·449	≈ 2·4	rounded to one decimal places
25·0478	≈ 25·048	rounded to three decimal places
25·0478	≈ 25·05	rounded to two decimal places
25·0478	≈ 25·0	rounded to one decimal place.

ANNEX D

CALCULATION OF THE LOWER AND UPPER LIMITS FOR THE AVERAGE OUTER DIMENSIONS OF CABLES WITH CIRCULAR COPPER CONDUCTORS

D-1 GENERAL

D-1.0 This specifies a method for calculation of the lower and upper limits for the average outer diameter of cables with circular copper conductors.

D-2 LOWER LIMIT FOR THE AVERAGE OUTER DIAMETER

D-2.1 Take a diameter D of the conductor the value given in Table 5 for cables for fixed wiring.

D-2.2 Calculate the nominal diameter over the core by adding to the appropriate value of the conductor diameter, obtained as in **D-2.1**, twice the specified mean value of the thickness of the insulation and of any other mandatory coverings of the individual core.

D-2.3 Calculate the nominal diameter over the core assembly by multiplying the value obtained in **D-2.2**, by the appropriate value of the assembly coefficient k, given in Table 4.

Table 4

Number of Cores	Assembly Coefficient (k)	Number of Cores	Assembly Coefficient (k)
2	2·00	24	6·00
3	2·16	25	6·00
4	2·42	26	6·00
5	2·70	27	6·15
6	3·00	28	6·41
7	3·00	29	6·41
7*	3·35	30	6·41
8	3·45	31	6·70
8*	3·66	32	6·70
9	3·80	33	6·70
9*	4·00	34	7·00
10	4·00	35	7·00
10*	4·40	36	7·00
11	4·00	37	7·00
12	4·16	38	7·33
12*	5·00	39	7·33
13	4·41	40	7·33
14	4·41	41	7·67
15	4·70	42	7·67
16	4·70	43	7·67
17	5·00	44	8·00
18	5·00	45	8·00
18*	7·00	46	8·00
19	5·00	47	8·00
20	5·33	48	8·15
21	5·33	52	8·41
22	5·67	61	9·00
23	5·67		

*Cores assembled in one layer.

D-2.4 Calculate the nominal outer diameter D_o of the finished cable by adding to the value obtained in **D-2.3** twice the specified mean value of the thickness of the sheath (or sheaths) and of the other mandatory covering, if any, over the core assembly (*see* **D-4**).

D-2.5 The lower limit D_{min} of the average outer diameter is obtained by multiplying D_0 by 0·97 and rounding off the value obtained:

- to the nearest lower first decimal, if $0{\cdot}97\ D_0 \leqslant 5$ mm
- to the nearest lower even first decimal, if $5 \text{ mm} < 0{\cdot}97\ D \leqslant 10$ mm
- to the nearest lower half-unit, if $0{\cdot}97\ D_0 > 10$ mm.

Examples:

If $0{\cdot}97\ D_0 = 4{\cdot}33$ $\quad D_{min} = 4{\cdot}3$

$0{\cdot}97\ D_0 = 7{\cdot}33$ $\quad D_{min} = 7{\cdot}2$

$0{\cdot}97\ D_0 = 11{\cdot}33$ $\quad D_{min} = 11{\cdot}0$

$0{\cdot}97\ D_0 = 11{\cdot}83$ $\quad D_{min} = 11{\cdot}5$

D-3 UPPER LIMIT FOR THE AVERAGE OUTER DIAMETER

D-3.1 Take as diameter D of the conductor the value given in Table 5.

D-3.2 Calculate the nominal diameter over the core by adding to the appropriate value of the conductor diameter obtained as in **D-3.1**, twice the specified mean value of the thickness of the insulation and all (both mandatory and optional) coverings over the conductor, specified for the cable in question.

D-3.3 Calculate the nominal diameter over the core assembly by multiplying the value obtained in **D-3.2**, by the appropriate assembly coefficient, k, given in **D-2.3**.

D-3.4 Calculate the nominal outer diameter D_1 of the finished cable by adding to the value obtained in **D-3.3**, twice the specified mean value of the thickness of the sheath (or sheaths) and of all (both mandatory and optional) other coverings over the core assembly, specified for the cable of cord in question, *see* **D-4**.

D-3.5 The upper limit D_{max} of the average outer diameter is calculated to two decimal places as follows:

$$D_{max} = 1{\cdot}05\ D_1 + X$$

where

$X = 0{\cdot}3$ mm for single core cable if $D_1 \leqslant 5$ mm.

$X = 0.4$ mm for single core cables if $D_1 > 5$ mm, and for multicore cables if $D_1 \geqslant 5$ mm.

$X = 0.5$ mm for multicore cables if $D_1 > 5$ mm.

D_{max} is rounded off in a similar way as D_{min} (*see* **D-2.5**) but to the nearest higher value instead of the nearest lower value.

Examples:

If $1.05\ D_1 + X = 4.84$ $D_{max} = 4.9$

$1.05\ D_1 + X = 9.23$ $D_{max} = 9.4$

$1.05\ D_1 + X = 12.11$ $D_{max} = 12.5$

$1.05\ D_1 + X = 12.62$ $D_{max} = 13.0$

D-4 THICKNESS OF THE MANDATORY OR OPTIONAL COVERINGS OTHER THAN THE INSULATION AND THE SHEATH(S)

Separator between conductor and insulation ....0·08 mm

Proofed textile tape, textile braid round each core..................0·15 mm

Separator between layers of a sheath.......................0·15 mm

Outer textile braid..........................0·30 mm

Metal..2·5 x (diameter of the component wire in millimetres)

Table 5 Lower and Upper Limits of Diameter of Circular Copper Conductors for Cables for Fixed Wiring

(*Clause* D-3.1)

Nominal Cross-Sectional Area	Class 2 Diameter of Conductor*	
	Lower Limit	Upper Limit
mm^2	mm	mm
(1)	(2)	(3)
1	1·19	1·33
1·5	1·47	1·64
2·5	1·86	2·07
4	2·36	2·63
6	2·89	3·22
10	3·75	4·18
16	4·72	5·26
25	5·95	6·62
35	7·00	7·80
50	8·15	9·08
70	9·79	10·9
95	11·5	12·9
120	13·0	14·4
150	14·4	15·9
185	16·1	17·9
240	18·5	20·3
300	20·7	22·7

*It is stressed that the conductor diameters are intended for the purpose of this method only.

The conductor diameters have been calculated with the data given in the Tables of IS 8130 : 1984.

Any change in the said tables may change the values of the diameters in this Annex.

ANNEX E

(*Clause* 10.3)

PROCEDURE FOR CHECKING THE EFFICACY OF THE METHOD OF SPARK TESTING

E-1 OBJECT

E-1.0 The object of this procedure is to standardize the method by which manufacturers may demonstrate that their spark testing method is effective in detecting faults in the insulation as specified in **10.3** (b) (*see* Fig. 1).

The manufacturer's instructions for production and control procedures shall provide that cables for which spark testing is required shall be effectively tested in practice.

E-2 PROCEDURE

E-2.1 Manufacturers should have available two test-lengths of cores which have been specially prepared. One of the cores should have the smallest insulation thickness for the relevant types of cable, the other core should have the largest insulation thickness for the relevant type of cable (*see* Fig. 2).

E-2.2 The preparation of the punctures in the insulation shall be effected as follows:

a) The insulation shall be removed from the core for a length of about five times the nominal thickness.

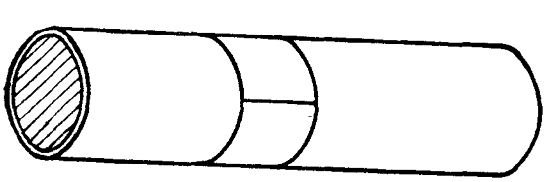

FIG. 1

b) Form the piece of insulation which has been removed, a segment of about 30° shall be removed; the remaining piece of insulation shall then be replaced on the conductor.

c) Over the replaced piece of the insulation, one layer of adhering tape (for example, PE terephthalate) shall be placed in a longitudinal direction, with an overlap. This overlap shall be situated on the opposite side of the core to the position where the insulation was removed.

The layer shall have a length of at least ten times the nominal insulation thickness.

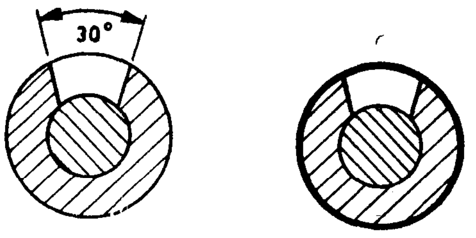

FIG. 2

d) In this layer, in the middle of the place where the insulation has been removed, a hole in the tape shall be punched with a hot needle. The diameter of this hole shall be equal to half of the allowed minimum insulation thickness.

The other test piece shall be prepared in the same way.

E-2.3 The prepared test-pieces should then be passed through the spark test equipment at the highest speed for which the equipment is intended, the voltage applied between the electrode and the conductor being that normally used.

The equipment shall register one fault when each test piece is spark tested.

E-2.4 Method to check the recovery time.

At least two f ults shall be passed through the spark-test equipment at its actual operating speed *v* (in metre per second), the distance in metres between two faults being not greater than the value of *v*.

All the faults shall be registered by the equipment.

ANNEX F

(*Clauses* 4.2 *and* 11.11)

TEST OF THE METAL COATING OF COPPER WIRES

F-1 PREPARATION OF SPECIMENS

F-1.0 A 0·30 m long cable sample should be dismantled to expose the copper conductors avoiding damage to the metal coating over the wires. Several wire pieces should be taken from the outer layer of each conductor and should be cut in shorter sections which will permit complete immersion for the persulphate solution.

The wires should be thoroughly cleaned with a suitable solvent and wiped dry with a clean soft cloth. The ends of each wire portion should be completely coated with wax to protect the exposed copper.

Two specimens should be so prepared from the cable sample. The total length of each specimens should be calculated with the formula $L = 300/d$ where d is the nominal wire diameter, both L and d being expressed in mm (or $l = 0{\cdot}465/d$ both L and d being expressed in inches). The wax coated ends should not be included in determining the length L.

F-2 SPECIAL SOLUTIONS

a) *Test Solution (Ammonium Persulphate)*

Dissolve 10 grams of ammonium persulphate ($NH_4)_2S_2O_8$ (crystals containing not less than 95 percent of ammonium persulphate) in 500 ml of distilled water. Add 75 ml of chemically pure solution of ammonia (density 0·90) and dilute to 1 *l* with distilled water.

The ammonium persulphate solution should be freshly prepared each day tests are to be conducted and should not be subjected to temperature above 35°C.

b) *Reference Colour Standard (Copper Sulphate — Ammonium Dioxide)*

Dissolve 0·200 g of anhydrous copper sulphate ($CuSO_4$) in distilled water, add 75 ml of a chemically pure solution of ammonia (density 0·90) and dilute to 1 *l*.

F-3 TEST PROCEDURE

F-3.0 Each specimen of the required length L should be immersed in 100 ml of the test solution, using as container a test tube of appropriate dimensions. The specimens should be left immersed in the test solution at a temperature of 20 ± 3°C for a period of 15 min. The specimen should then be removed and the test solution compared with an equal depth of the reference colour standard contained in a similar test tube. The colour comparison should be made by viewing the solutions lengthwise through the test tube.

The colour of the test solution after immersion of the test specimen should not be darker than that of the reference colour standard solution. Both specimens should comply with this requirement.

ANNEX G

(*Clauses* 8.2, 8.3 *and* 11.12)

GALVANIZING TEST FOR STEEL WIRES

G-1 Five specimens, 200 mm long, should be cleaned with a piece of wadding soaked in benzene and dried.

The specimens should be immersed one by one in a glass vessel with a height of 160 mm and a diameter of 35 mm about four-fifths full of a solution of copper sulphate. The liquid should not be stirred. After 1 min the specimen should be removed from the liquid and immediately cleaned in running water with the aid of a piece of wadding to remove spongy precipitation of copper.

This operation should be repeated with the same liquid until a adherent precipitation of copper occurs, which cannot be removed with the wadding. The part of the specimen within 30 mm from the submerged end is not considered.

For each specimen a fresh solution shall be used. This solution should contain one part of copper sulphate ($CuCo_4 . 5H_2O$) in five parts of water (187 g/l). After complete dissolution, an addition is made of 1 g to 2 g per litre of copper hydroxide or powdered copper carbonate or copper oxide, in order to neutralize the free sulphuric acid generally contained in the copper sulphate used for the solution. The solution should be kept at a temperature of 20 ± 0·5°C.

The average number of immersions for the five specimens should not be less than the number indicated in the following Table 6 before non-removable red copper appears on the specimen as stated above.

Table 6 Number of Immersions for the Galvanizing Test

Nominal Diameter of Round Wires or Thickness of Shaped Wires		Minimum Number of Immersions
Exceeding (mm)	Not exceeding (mm)	(of 1 min)
(1)	(2)	(3)
0·8	1·3	1
1·3	2·0	2
2·0	2·5	3
2·5	5·1	4

NOTES

1 Wires having a diameter not exceeding 0·8 mm should withstand at least one dip of 1/2 minute.

2 It sometimes happens that copper is deposited on the zinc coating itself, giving a false appearance of failure. Such a deposit may be tested for adherence after the completion of the final dip, either by peeling, light rubbing, or by immersion in a solution of hydrochloric acid (1/10) for 15 s, followed by immediate rinsing in clean running water with vigorous scrubbing. If the copper has been removed, the zinc appears underneath, the sample should not be deemed to have failed.

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